Low-speed modems are easy to design

with ICs. They can perform all of the necessary functions, from tone generation to signal conversion.

For some engineers, the design of a data modem (modulator/demodulator) is still a major project. But in low-speed applications, in which simple frequency-shift keying (FSK) suffices, all of the blocks in the modem block diagram can be realized by using one or more ICs (Fig. 1).

Line drivers and receivers that conform to EIA specification RS-232 (see box) are available in quad ICs (four drivers or receivers per package). The control logic and signal-converter circuitry usually consist of an assortment of standard digital ICs, with perhaps an op amp included in the signal converter to provide it with a frequency-discrimination capability. And the main components in the tone generator and the active filters are usually a bunch of IC op amps.

Hysteresis needed in line receiver

Since the line receiver will usually be purchased as a single component, it is more important to know how to buy one than how to build one.

One important fact to bear in mind is that most modems have eight to 16 lines connecting them with the computer terminal. To save space, therefore, it is desirable to use line-receiver chips that contain several complete receivers per package.

A second important characteristic to look for is high input hysteresis. Without it the line receiver will be too susceptible to input noise. This point is so important that the Motorola MC1489A line driver (Fig. 2) has been designed to have more than four times as much hystersis as its predecessor, the MC1489. The later model has a typical turn-on threshold of 2 V, but it doesn't turn-off until the input voltage falls below 0.8 V. The earlier units had only 250 mV of hysteresis.

The entire hysteresis loop is above ground, so that the receiver meets the fail-safe requirements of RS-232-C. This means the receiver output always goes to a mark condition when the input sees an open circuit.

A third desirable characteristic is a provision

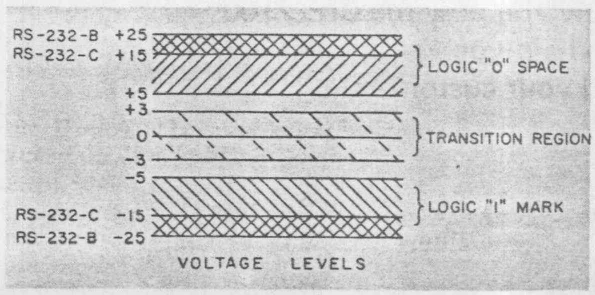
Clay Tatom, Manager, Communications Marketing, Motorola Semiconductor Products, Inc., P.O. Box 20906, Phoenix, Ariz. 85036

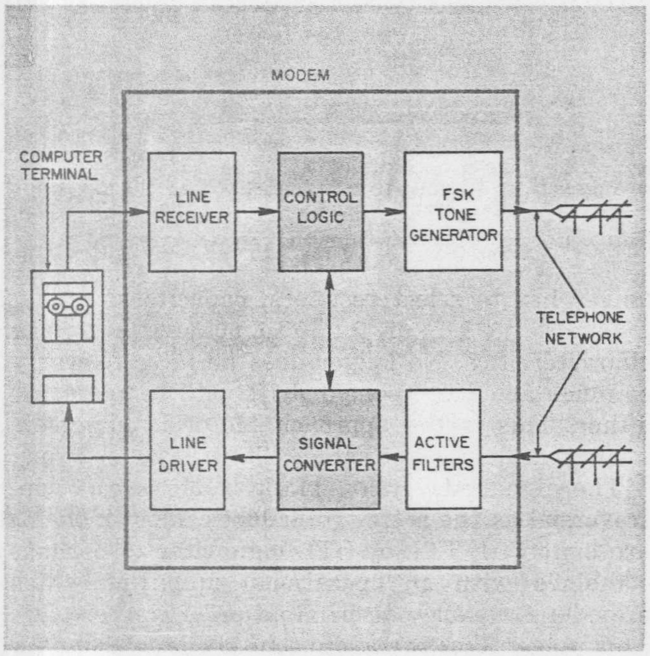
What is EIA spec RS-232?

The Electronic Industries Association (EIA) has standardized a specification to which the voltage and the impedance levels of the ONEs and ZEROs on the computer side of the modem must conform so that any modem can talk to any computer with which it might be mated. So, the RS-232 specification standardizes the voltage and impedance levels at the computer-modem interface (not at the modem-telephone interface). Two different versions of this specification exist: the older RS-232-B spec and the newer RS-232-C. Most modems being designed today for industrial use conform to the RS-232-C spec. The most important features of this specification are given below.

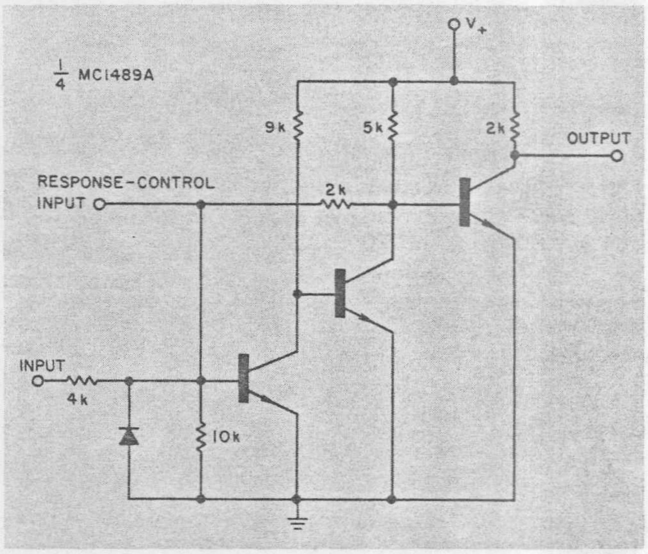
Electrical Specifications

Driver output logic levels with 3k to 7k load	15 V $>$ V_{OH} $>$ 5 V −5 V $>$ V_{OL} $>$ −15 V
Driver output voltage with open circuit	$\lvert V_o \rvert$ $<$ 25 V
Driver output impedance with power off	Z_o $>$ 300 ohms
Output short circuit current	$\lvert I_o \rvert$ $<$ .5 A
Driver slew rate	dv/dt $<$ 30 V/μs
Receiver input impedance	7k ohms $>$ R_{in} $>$ 3k ohms
Receiver input voltage	±25 V compatible with driver
Receiver output with open circuit input	mark
Receiver output with 300 ohms to ground on input	mark
Receiver output with +3 V input	space
Receiver output with −3 V input	mark





1. **Each of the blocks in this modem can be realized with one or more ICs.** Only the tone generator and filters will need some passive components. When working with the switched telephone network, a Data Access Arrangement must connect the modem with the network.



2. **This line receiver has over a volt of hysteresis.** The response-control input can be used to shift the input threshold by returning it to an auxilliary supply voltage through an external resistor; it can be used to provide extra noise filtering by returning it to ground through an external capacitor; or it can be used to connect two receivers in parallel to the same input line by tying the line to them through 8-kΩ resistors.

for threshold shifting. This enables the unit to be used in the control-logic circuitry as a level translator between MOS devices and TTL or DTL circuits.

The control logic itself is usually a section of TTL, DTL or MOS logic circuits that control the tone generator, FSK, and/or signal-conversion stages of the modem. The actual logic varies with the modem manufacturer, but most use this control section to gate the FSK switches on or off and to drive the inputs of the line drivers.

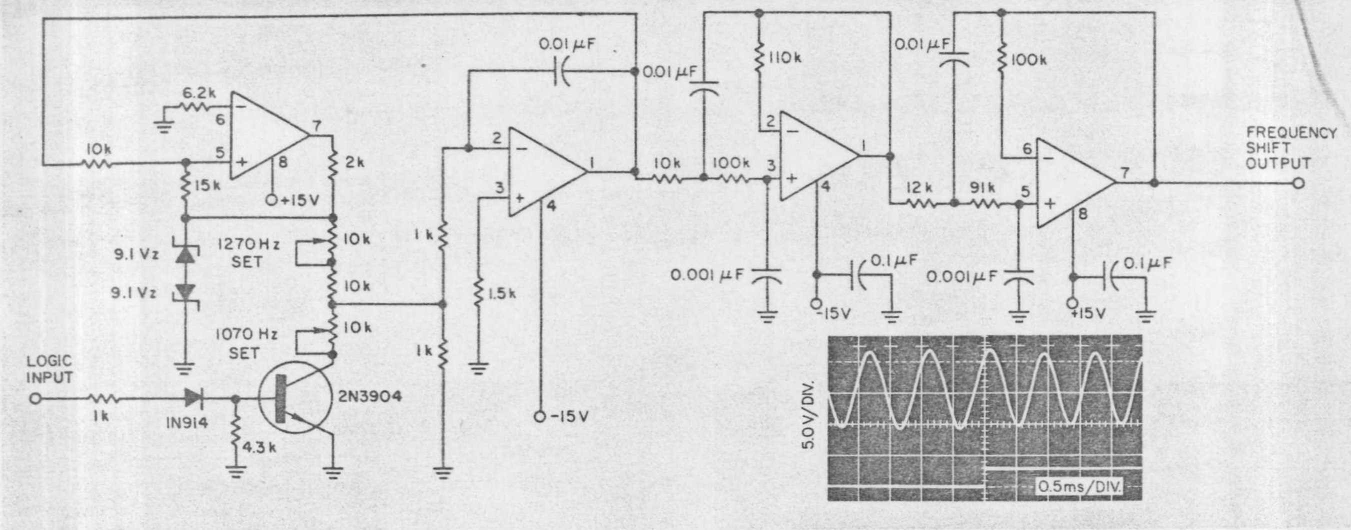
This FSK unit uses four op amps

Although highly sophisticated modulation techniques are needed for high-speed data transmission, most low-speed systems being built today use simple FSK tone generators, such as the one shown in Fig. 3. The circuit features an integrator/Schmitt-trigger loop with fourth-order filtering for the output signal. A pair of dual op amps is used to minimize the parts count. Good stability is ensured by the zener clipping at the trigger input.

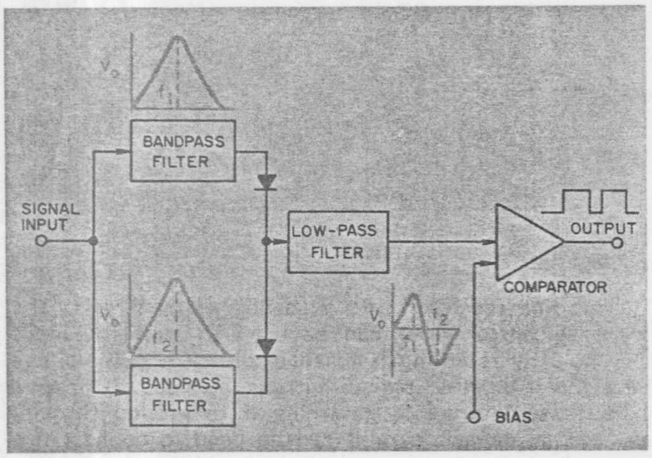
Variable frequencies are generated by changing the input transconductance to the integrator through a Tee network. Shunt switches may then be used to frequency shift from 1070 Hz to 1270 Hz, for the example shown. The integrator amplitude is constant with this approach, and its harmonics are easily filtered.

The filter employed is a modified double-section, second-order Butterworth type, with slightly more peaking than normal to equalize the signal amplitudes and still retain maximum harmonic suppression. Ordinary Sallen-Key type low-pass filters are used since the corner frequencies are not critical and the relative Q is 1.

The active-filter section of the modem is probably the most controversial of all the blocks.



3. **This FSK tone generator has good stability** because of the zener-diode clipping at its input. The output frequency shifts from 1070 to 1270 Hz when the input changes from a mark to a space. Each of the op amps is half of an MC1458G. The waveform shows phase continuity during tone switching.



4. **Here's one way to build a low-speed signal converter.** This circuit is essentially the opposite of a tone generator—its output changes logic levels when its input frequency changes.

Designers of active filters usually have their own preferred technique. So long as it works for them, they are often not inclined to explore the advantages of other approaches.

Motorola has worked with several techniques. One is the Sallen-Key method shown in the tone generator. Another is the "bi-quadratic" technique, which has been around Bell Telephone Laboratories a long time but has become popular only recently, because the low-cost IC op amp made it economically feasible. This technique requires several active elements instead of only one, but this trade-off today usually results in production-cost savings as well as other advantages.

The big advantage of the "bi-quadratic" filter is that when the designer uses the several active op-amp elements that the design requires, he no longer has to select resistors, capacitors, and/or inductors to 1% or 0.1% to achieve his filter characteristics. No longer does he have to worry so much about component drift with temperature either. This is the approach Motorola engineers recommend for most active filters in a modem.[1]

The signal-conversion block is almost as controversial as the active-filter block. Most modems are built with TTL or DTL logic circuits perhaps combined with an operational amplifier which provides frequency-discrimination characteristics. This stage takes the audio tones coming from the active filter and demodulates them to give either a ONE or a ZERO depending upon which frequency tone is present. Usually the output is at TTL logic levels. Like the active-filter section, designs are so varied that no standard circuit exists for this block of the modem, although a typical circuit might look like that of Fig. 4.

Don't let the driver slew too fast

The last block of Fig. 1 that remains to be discussed is the RS-232 line driver. As with the line receiver, quad packaging is desirable since eight to 16 lines usually have to meet the RS-232-C interface specification.

A point worth noting is that RS-232-C specifies a maximum slew rate of 30 V/μs. Some drivers, such as the Motorola MC1488, will exceed this rate if they are made to work into less than 330 pF of capacitance. For very short lines, therefore, an external capacitor may be needed to roll the slew rate down to the 30 V/μs maximum. ■■

Reference:

1. *Motorola Integrated Circuits for Modem and Terminal Systems*, 1970.